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FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: **203495US2PCT**

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR: 09/786275

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR99/02102	**03 SEPTEMBER 1999**	**04 SEPTEMBER 1998**

TITLE OF INVENTION

METHOD FOR RECEIVING CDMA SIGNALS WITH SYNCHRONIZATION BEING OBTAINED THROUGH DOUBLE DELAYED MULTIPLICATION, AND ASSOCIATED RECEIVER

APPLICANT(S) FOR DO/EO/US

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Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☒ has been transmitted by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ have been transmitted by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Request for Consideration of Documents Cited in International Search Report
Notice of Priority
Amended Sheets (pages 3, 5, 18, 19 and 19A)
Drawings (4 sheets)
PCT/IB/304
PCT/IB/308

PCTUS1/REV03

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/786275	INTERNATIONAL APPLICATION NO. PCT/FR99/02102	ATTORNEY'S DOCKET NUMBER 203495US2PCT

21. The following fees are submitted:.

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1,000.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO **$860.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	5 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
	TOTAL OF ABOVE CALCULATIONS =			**$990.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable).** ☐				**$0.00**	
	SUBTOTAL =			**$990.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
	TOTAL NATIONAL FEE =			**$990.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
	TOTAL FEES ENCLOSED =			**$990.00**	
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☒ A check in the amount of **$990.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees. A duplicate copy of this sheet is enclosed.

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NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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METHOD FOR RECEIVING CDMA SIGNALS WITH SYNCHRONIZATION ~~BEING OBTAINED THROUGH DOUBLE DELAYED~~ MULTIPLICATION, AND ASSOCIATED RECEIVER

Technical field

The present invention relates to a method for receiving CDMA signals with synchronization being obtained through double delayed multiplication, and an associated receiver.

The acronym CDMA means "Code Division Multiple Access" and refers to a digital communications technique wherein several users use the same communications channel by means of a special allocation of pseudo-random sequences (or codes).

Prior art

The CDMA technique has been widely described in literature. In this respect, the following general books can be looked up:

- Andrew J. VITERBI: "CDMA-Principles of Spread Spectrum Communication" Addison-Wesley Wireless Communications Series, 1975,

- John G. PROAKIS: "Digital Communications" McGraw-Hill International Editions, 3rd edition, 1995.

It is also possible to look up patent documents issued by the applicant, and in particular: FR-A-3 712 129, FR-A-2 742 014, and FR-A-2 757 333.

The techniques described in these documents implement a signal theory that can be summed up briefly for better understanding of the invention. A pulse

carrier w is considered, phase-modulated by a time function P(t). The modulated signal can be written as:

$$s(t) = A(t)\cos[wt+P(t)]$$

where A(t) is signal amplitude.

This expression can be expanded to become:

$$s(t) = A(t)\cos wt \cos P(t) - A(t)\sin wt \sin P(t)$$

In designating part A(t)cos P(t), which is in phase with the carrier, as I(t) and part A(t)sin P(t), which is in quadrature therewith, as Q(t), this signal can also be written like this:

$$s(t) = I(t)\cos wt - Q(t)\sin wt$$

Processing of signal s(t) can thus be done by double processing of parts I(t) and Q(t) which will be designated more simply as I and Q hereafter.

Receivers processing such signals generally receive such signals I and Q at two distinct inputs. They are obtained by multiplying the receive signal by a wave either in phase with the carrier, or in quadrature therewith. The circuits then perform various processing operations depending on the modulations used. Thus, for differential phase modulation, processing consists in calculating the sum and the difference of delayed or undelayed sample products, e.g. $(I_kI_{k-1}+Q_kQ_{k-1})$ and $(Q_kI_{k-1}-I_kQ_{k-1})$, where k designates sample rank.

The first expression is a so-called "DOT" expression and the second one a "CROSS" expression. The DOT signal allows phase displacement between two successive symbols to be determined, whereas DOT and CROSS signals considered together allow to determine the integer times $\pi/2$ of the phase displacement between

successive symbols. The DOT and CROSS signals considered together allow to determine the integer times $\pi/2$ of the phase displacement between successive symbols. These DOT and CROSS signals thus enable correct and unambiguous demodulation when differential phase modulation has been used at the transmitter.

Documents FR-A-2 742 014 or FR-A-2 757 330 describe a receiver implementing this technique. This receiver is represented in the appended Fig. 1. It comprises two similar channels, one phase processing component I and the other quadrature processing component Q. The first channel has a first means 10(I) for fulfilling a filter function suitable for the pseudo-random sequence used at the transmitter, and a delay means 12(I). Like the first one, the second channel comprises a second means 10(Q) for fulfilling a filter function suitable for said pseudo-random sequence, and a delay means 12(Q).

The circuit also comprises a binary multiplier 14 having:

- two first inputs, one connected to the output of the first digital filter means 10(I) and receiving a first filtered signal I_k, and the other one connected to the output of the first means for fulfilling the delay function 12(I) and receiving a first filtered-delayed signal I_{k-1},

- two second inputs, one connected to the output of the second filter means 10(Q) and receiving a second filtered signal Q_k, and the other one connected to the output of the second means for fulfilling the delay function 12(Q) and receiving a second filtered-delayed signal Q_{k-1},

- a means for calculating the two direct products between filtered signals and filtered-delayed signals of the first and second channels, i.e. I_kI_{k-1} and Q_kQ_{k-1}, and the two crossproducts between the filtered signal of one channel and the filtered-delayed signal of the other channel, i.e. Q_kI_{k-1} and I_kQ_{k-1},

- a means for calculating the sum of the direct products, i.e. $DOT_k=I_kI_{k-1}+Q_kQ_{k-1}$ and the difference of the crossproducts, i.e. $CROSS_k=Q_kI_{k-1}-I_kQ_{k-1}$.

The circuit described in the above-mentioned documents also comprises a clock integration and regeneration circuit 16 receiving the sum of the direct products and the difference of the crossproducts.

Finally, this circuit comprises a digital programming means 18 containing information for programming, in particular the first and second filter means 10(I), 10(Q).

Figs. 3, 4, and 5 of the document FR-A-2 757 330 mentioned above show the appearance of the DOT and CROSS signals for differential phase shift keying (DPSK) or differential quadrature phase shift keying (DQPSK). These are peaks marked either positive or negative, according to the circumstances.

In such receivers, synchronization, which allows information data to be located in the filtered signal, is one of the basic operations. It is carried out by following the DOT and/or CROSS signal peaks and determining the time when these peaks cross a maximum. Document FR-A-2 742 014, already mentioned, describes a circuit substantially comprising a comparator, a register and a counter, a means allowing to generate a

pulse the leading edge of which is set on the peak received. This pulse is the synchronization signal.

The circuit of Fig. 1 can be slightly modified, as illustrated in Fig. 2, by adding a mean calculation circuit 22. In Fig. 2, the oval circuit 14 is supposed to symbolize delayed sample multiplication, i.e. multiplying one sample by the conjugate preceding sample. Value T_b is the duration of one information bit (or symbol).

Circuit 20 is a circuit searching for the maximum of $|DOT_k|$ and $|CROSS_k|$, and circuit 22 is a circuit calculating an average. An example of this circuit is represented in Fig. 3. It comprises a multiplier 23, a $1/2^m$ gain circuit 24, a delay circuit 25 of quantity T_b corresponding to the duration of one data bit, and a 2^m-1 gain circuit 26 closing on multiplier 23.

If X(n) designates the input signal and Y(n) the output signal:

$$Y(n) = X(n-1) x Y(n-1) \frac{2^m - 1}{2^m}$$

is obtained, where m is a variable factor. The signal Y(n) is the final synchronization signal.

This receiving method and associated receivers, although being satisfactory in some respects, still lead to a certain risk of error in the information restored, which can be measured by a so-called bit error rate (BER) quantity.

It is precisely an object of the present invention to overcome this drawback by reducing this rate at the expense of minor modifications.

According to the invention, this improvement is obtained by implementing a so-called double delayed multiplication technique found in a specific type of detection, i.e. double differential detection. Double differential detection known in radio transmissions, in particular in satellite transmissions. However, it is only used for decoding information and not for synchronization. It is described, e.g. in the article by M.K. SIMON and D. DIVSALAR titled "On the Implementation and Performance of Single and Double Differential Detection Schemes" published in the magazine "IEEE Transactions on Communications", vol. 40, n°2, February 1992, pages 278-291.

The appended Fig. 4 recalls the principle of this double differential detection. The diagram represents a transmitter E and a receiver R. Inside transmitter E, there is substantially a first multiplier associated with a first delay circuit 32 of a duration equal to the duration of symbols to be transmitted, as well as a second multiplier 34 associated with a second delay circuit 36. At the receiver side R, there are similar means, i.e. a first multiplier 40 associated with a first delay circuit 42 as well as a second multiplier 44 associated with a second delay circuit 46. These means perform symmetrical information encoding and decoding. Data is encoded so that after decoding, decision making is independent of Doppler noise, as explained in the above-mentioned article.

It must also be stressed that this technique is not about synchronization but only encoding/decoding.

The present invention recommends the principle of double delayed multiplication to be used for improving the quality of synchronization. Moreover, the invention is part of CDMA, assuming information symbols to be spectrum spread by pseudo-random sequences, which is a field very far away from radio transmissions.

Summary of the invention

Precisely, the object of this invention is a method for receiving a CDMA signal, comprising an operation of correlation with appropriate pseudo-random sequences, an operation of synchronization for locating data within the correlation signal obtained, and a data retrieval operation, this method being characterized in that the synchronization operation implements double delayed multiplication of the correlation signal.

Also, an object of the invention is a CDMA receiver, comprising:

- correlation means functioning with appropriate pseudo-random sequences, and delivering a correlation signal,

- synchronization means for delivering a synchronization means locating data in the correlation signal,

- decoding means for retrieving the data,

this receiver being characterized in that the synchronization means is a correlation signal double delayed multiplication means.

Brief description of the drawings

- Fig. 1, already described, illustrates a known receiver;
- Fig. 2, already described, illustrates a specific embodiment of the synchronization means;
- Fig. 3, already described, shows the principle of a signal averaging circuit;
- Fig. 4, already described, illustrates the principle of double differential detection used for encoding and decoding information data;
- Fig. 5 schematically illustrates the double delayed multiplication method implemented in the invention;
- Fig. 6 shows the appearance of a processed signal;
- Fig. 7 is a diagram showing the relationships existing between various differential quantities;
- Fig. 8 comparatively illustrates the performance of a receiver in accordance with the invention.

Description of specific embodiments

Fig. 5 schematically illustrates the synchronization part of a receiver in accordance with the invention. The adapted filters (or correlators), the decoding means, etc. are not shown because they have already been described in Fig. 1. Furthermore, it is assumed that complex signals with a (phase, or real) component I and a (quadrature, or imaginary) component Q are processed.

The circuit of Fig. 5 receives samples I_k and Q_k indexed according to their rank k. Double delayed

multiplication is obtained, on the one hand, by circuit 50 and delay circuits 52, 54, for the first delayed multiplication, and on the other hand, by circuit 60 and delay circuits 62, 64 for the second one. The represented circuit is completed with a maximum indexing circuit 66 and a signal averaging circuit 68.

The first multiplication allows the components $DOT_k^{(1)}$ and $CROSS_k^{(1)}$ to be obtained, which are defined by

$$DOT_k^{(1)} = I_k I_{k-1} + Q_k Q_{k-1}$$

$$CROSS_k^{(1)} = I_{k-1} Q_k + I_k Q_{k-1}$$

The upper index (1) recalls that samples obtained after a first delayed multiplication are involved.

The second multiplication allows to obtain two further components, indicated by an upper index (2), i.e.:

$$DOT_k^{(2)} = DOT_k^{(1)}.DOT_{(k-)1}^{(1)} + CROSS_k^{(1)}.CROSS_{(k-1)}^{(1)}$$

$$CROSS_k^{(2)} = DOT_{(k-1)}^{(1)}.CROSS_k^{(1)} - DOT_k^{(1)}.CROSS_{(k-1)}^{(1)}$$

Synchronization according to the invention is performed on signals $DOT^{(2)}$ and $CROSS^{(2)}$.

In order to understand why double delayed multiplication provides an advantage in comparison with single multiplication, we have to return to the theory of spread spectrum digital communications using pseudo-random sequences and calculate the probability of peak detection.

A baseband signal corresponding to the message transmitted by the u-th user can be written as:

$$s_u(t) = \sqrt{P_u}\, b_u(t) a_u(t) e^{j\phi_u},$$

where:

- P_u is the energy received at the receiver;

- $b_u(t) = \sum_{i=0}^{M-1} b_{i,u} p_{T_b}(t - iT_b$, is data transmitted, where $b_{i,u}$ adopt the values +1 or −1, M being the number of bits contained in the block of information under consideration:

$$p_{T_b}(t) = \begin{cases} 1 \text{ if t is in range } 0 - T_b \\ 0 \text{ if t is outside this range} \end{cases}$$

- $a_u(t)$ is the spread spectrum sequence, i.e. $a_u(t) = \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} X_j^k P_{T_c}(t - jT_c - iT_b$, where $N = \frac{T_b}{T_c}$ is the processing gain or sequence length, X_j^0 adopts the values +1 or −1 and T_c is the duration of a rectangular chip;

- θ_u is a phase (with respect to a reference phase).

Because of system inherent asynchronism, the total signal received is written as:

$$r(t) = \sum_{u=1}^{U} S_u(t - \tau_u) + n(t ,$$

where:

- U is the number of users;

- τ_u, comprised in range (0, T_b), is the delay associated with the u-th user;

- n(t) is a white gaussian noise with $\frac{N_0}{2}$ one-way power spectral density.

This conventional notation assumes:

- no multiple tracks,

- no phase rotations during transmission (no fade-out or Doppler effect),

- channel invariance during transmission,
- infinite band channel (signals are perfectly rectangular).

The outputs of the filters adapted to U spread spectrum sequences are the components of a vector designated as $\bar{y}$.

The complex envelope of vector $\bar{y}$ is written as:

$$\bar{y} = \bar{y}_I \cos(\Theta) + \bar{y}_Q \sin(\Theta$$

The i-th output of the filter adapted to the u-th user is the ((i-1)U+u)-th element of this vector $\bar{y}$.

The quantity Θ is a UM ranked diagonal matrix, the elements of which are the phases associated with the i-th bit of the u-th user.

The phase and quadrature components of y are written as:

$$\begin{cases} y_{I_{(i-1)U+u}} = y^{I}_{i,u} = \displaystyle\int_{(i-1)T_b+\tau_u}^{iT_b+\tau_u} r_I(t)a_u(t-\tau_u)dt \\ y_{Q_{(i-1)U+u}} = y^{Q}_{i,u} = \displaystyle\int_{(i-1)T_b-\tau_u}^{iT_b+\tau_u} r_Q(t)a_u(t-\tau_u)dt \end{cases}$$

where $r_I(t)=\mathrm{Re}[r(t)]$ and $r_Q(t)=\mathrm{Im}[r(t)]$. In matrix form, this can be written as:

$$\begin{cases} \bar{y}_I = RW\cos(\Theta)\bar{b} + \bar{n}_I \\ \bar{y}_Q = RW\cos(\Theta)\bar{b} + \bar{n}_Q \end{cases}$$

where:

- R is a UM ranked square matrix:

$$R = \begin{pmatrix} R(0) & R(1) & & & O \\ R(-1) & R(0) & R(1) & & \\ & R(-1) & R(0) & \ddots & \\ & & \ddots & \ddots & R(1) \\ & O & & R(-1) & R(0) \end{pmatrix}$$

- The (u,ℓ)-th element of the square matrix of rank K, R(i) is:

$$\rho_{u,\ell}(i) = \int_{-\infty}^{+\infty} a_u(t - \tau_u)a_\ell(t^0 iT_b - \tau_\ell)dt$$

- W is a UM ranked diagonal matrix, the elements of which are the square roots of the powers received, and defined in the same way as Θ;
- $\bar{b}$ is a UM sized vector, the j-th element (j=(i-1)U+u) of which is the i-th symbol transmitted by the u-th user,
- $\bar{n}_I$ and $\bar{n}_Q$ are color noise vectors.

If $\tau_1<\tau_2<\ldots<\tau_U$, then R(1) is an upper triangular matrix with zero diagonal, $R(-1)=R(1)^T$ where T is a translation, and R(i)=0, whatever |i|>1. This non restrictive hypothesis does by no means degrade the generalization of the proposed notation.

We are now considering the outputs of the correlation in a time window having the same duration as the bit duration. Except for the peaks, the signals at these outputs are written as: $\int_0^{T_b} r_1(t)a_u(t - nT_c)dt = r_{u,n}$, (r for real part, channel I).

This notation can be simplified as r_u (respectively i_u for the imaginary part of channel Q)

to designate the correlation outputs on channels I and Q, for a time window T_b.

Fig. 6 shows the appearance of signal r_u with a background 69 and a peak 70, the dashed frame symbolizing the time window corresponding to one data bit. If these outputs do not contain any signal (except for the peak), r_u and i_u can be modeled using gaussian zero average methods, and probabilities can be written as:

$$\begin{cases} p(r_u) = \dfrac{1}{\sqrt{2\pi\sigma}} e^{-\frac{r_u^2}{2\sigma^2}} \\ p(i_u) = \dfrac{1}{\sqrt{2\pi\sigma}} e^{-\frac{i_u^2}{2\sigma^2}} \end{cases}$$

where:

$$\sigma^2 = \sigma_{N_0}^2 + \frac{U-1}{3N}$$

for asynchronous transmissions. For the scenarios considered in the invention, $\sigma_{N_0}^2$ is much less than $\frac{U-1}{3N}$, so that $\sigma^2 \approx \frac{U-1}{3N}$.

After differential demodulation, synchronization can be considered as square-law detection, where the sum of squares $r_u^2 + i_u^2$ is determined (strictly speaking, $r_{u,n}r_{u,n-N}+i_{u,n}i_{u,n-N}$ is calculated, but the exponent can be simplified by taking $r_u^2 + i_u^2$). This quantity is the square of the amplitude A_k of the vector of components r_u, i_u:

$$A_u^2 = r_u^2 + i_u^2.$$

An angle ϕ_u, such as:

$$\begin{cases} r_u = A_u \cos(\phi_u \\ i_u = A_u \sin(\phi_u \end{cases}$$

can be defined.

If $p(r_u, i_u)$ and $q(A_u, \phi_u)$ designate the common probabilities relating to (r_u, i_u) and (A_u, ϕ_u):

$$p(r_u, i_u)dr_u di_u = \frac{1}{2\pi\sigma^2} e^{-\frac{r_u^2 + i_u^2}{2\sigma^2}} dr_u di_u = \frac{1}{2\pi\sigma^2} e^{-\frac{A_u^2}{2\sigma^2}} dr_u di_u = q(A_u, \phi_u)dA_u df_u$$

is obtained.

The Cartesian differential elements dr_u and di_u are related to the polar differential elements dA_u, $d\phi_u$ according to the diagram of Fig. 7. The area of the rectangle is $dr_u.di_u$ and the area of the circular segment is $(A_u d\phi_u)dA_u$. It can be considered that these two surfaces are substantially equal and:

$$dr_u di_u = A_u d\phi_u dA_u$$

can be written, leading to:

$$q(A_u, \phi_u) = \frac{A_u}{2\pi\sigma^2} e^{-\frac{A_u^2}{2\sigma^2}}.$$

A_u and ϕ_u are thus decorrelated and:

$$\begin{cases} q(\phi_u) = \dfrac{1}{2\pi} \\ q(A_u) = \dfrac{A_u}{\sigma^2} e^{-\frac{A_u^2}{2\sigma^2}} \end{cases}$$

If the correlation outputs contain a signal corresponding to the correlation peaks, their averages m_{r_u} and m_{i_u} are no longer zero and the probabilities (written with a dash) are now:

$$\overline{p}(r_u, i_u) = \frac{1}{2\pi\sigma^2} e^{-\frac{(r_u - m_u)^2 + (i_u - m_u)^2}{2\sigma^2}} = \frac{1}{2\pi\sigma^2} e^{-\frac{A_u^2}{2\sigma^2} - \frac{m_{r_u}^2 + m_{i_u}^2 - 2r_u m_{r_u} - 2i_u m_{i_u}}{2\sigma^2}} = \overline{q}(A_u, \phi_u)dA_u d\phi_u$$

and there are two quantities S_u and θ_u such as:

$$\begin{cases} m_{r_u} = S_u \cos(\theta_u \\ m_{u_u} = S_u \sin(\theta_u \end{cases}$$

$$\overline{q}(A_u) = \int_{\phi_u=0}^{2\pi} \frac{1}{2\pi\sigma^2} e^{-\frac{A_u^{2\phi}}{2\sigma^2} - \frac{S_u^2 - 2A_uS_u\cos(\phi_u - \theta_u)}{2\sigma_2}} d\phi_u = \frac{1}{\pi\sigma^2} e^{-\frac{A_u^2 + S_u^2}{2\sigma^2}} I_0\left(\frac{A_uS_u}{\sigma^2}\right)$$

is obtained, where I_0 designates the zero order Bessel function.

The probability of correct correlation peak detection is then:

$$P^{(1)} = \int_{\Re} q(A_u)\left(\int_{x=A_u}^{+\infty} \overline{q}(x)dx\right)dA_u$$

$$\text{i.e., } P^{(1)} = \int_{\Re} \frac{A_u e^{-\frac{A_u^2 + S_u^2}{2\sigma^2}}}{\pi\sigma^2}\left(\int_{A_u}^{+\infty} e^{-\frac{x^2}{2\sigma^2}} I_0\left(\frac{xS_u}{\sigma^2}\right)dx\right)dA_u$$

This calculation is valid for a single delayed multiplication, which explains the upper index (1) affecting P. It can be extended to the case of double delayed multiplication, and in general to the case of n delayed multiplications. The expressions then are:

$$A_u^2 = r_u^2 + i_u^n$$

$$\begin{cases} r_u^{(n)} = A_u^{2^{n-1}} \cos(\phi_u \\ i_u^{(n)} = A_u^{2^{n-1}} \sin(\phi_u \end{cases}$$

Probability is then expressed as:

$$\begin{cases} m_{r_u^{(n)}} = S_u^{2^{n-1}} \cos(\theta_u \\ m_{i_u^{(n)}} = S_u^{2^{n-1}} \sin(\theta_u \end{cases}$$

$$P^{(n)} = \int_{\Re^+} \frac{A_u e^{-\frac{A_u^{2^n} + S_u^{2^n}}{2\sigma^2}}}{2^{n-1}\pi\sigma^4}\left(\int_{(A_u)2^{n^1-1}}^{+\infty} e^{-\frac{x^2}{2\sigma^2}}(x)2^{\frac{1}{n-1}-1}\ I_0\left(\frac{x(S_u)^{2^{n-1}}}{\sigma^2}\right)dx\right)dA_u$$

The question is now whether this probability $P^{(n)}$ of correct peak detection increases when n (i.e., the number of delayed multiplications) is greater than 1.

The applicant has calculated this probability for the case of U=5 users, N=63 (sequences with 63 chips), and S_u=1. The results are grouped in the following table:

n	$P^{(n)}$
1	0,32
2	0,69
3	0,67
4	0,34
5	0,18

It appears that synchronization based on a double delayed multiplication is more reliable than conventional synchronization. On the other hand, increasing n beyond 2 does not modify anything other than increasing hardware complexity.

The curves of Fig. 8 enable a comparison between the performance obtained with the invention and that of conventional techniques. They show an evolution of the bit error rate (BER) as a function of the signal to noise ratio (SNR). In this figure:

- the three curves 71, 72, 73 correspond to a receiver having no stage for multiple access parallel interference suppression; curve 71 corresponds to prior art (single delayed multiplication), curve 72 corresponds to the invention (two delayed multiplications), and curve 73 is an ideal curve;

- the three curves 81, 82, 83 correspond to a receiver having a single stage for parallel interference suppression, with the same three

respective scenarios (single delayed multiplication, double delayed multiplication, ideal);

- the three curves 91, 92, 93 correspond to a receiver with two stages for parallel interference suppression with the same three successive scenarios;

- curve 95 corresponds to the ideal theoretical case.

These results show the interest of double delayed multiplication for synchronization. This operation is hardly more expensive than single delayed multiplication, except that it has to be duplicated for each channel. On the other hand, synchronization is greatly improved, enabling better retrieval and better estimates at each parallel interference suppression stage.

CLAIMS

1 .A method for receiving a CDMA signal, comprising an operation of correlation with appropriate pseudo-random sequences, an operation of synchronization for locating data in the correlation signal obtained, and an operation of retrieving data, this method being characterized in that the synchronization operation implements double delayed multiplication of the sampled correlation signal by performing a first delayed multiplication consisting in multiplying a sample of the correlation signal by the conjugate preceding sample (50, 52, 54), then a second delayed multiplication consisting in multiplying a sample of the signal thus obtained by the conjugate preceding sample of said signal obtained (60, 62, 64).

2. The method according to claim 1, wherein a maximum of the signal obtained through double delayed multiplication (66, 68) is searched for, and a synchronization signal (S) corresponding to said maximum is delivered.

3. The method according to claim 2, wherein an average is calculated of two successive maximum values obtained before the synchronization signal is generated.

4. The method according to claim 4, wherein, the correlation signal being a complex signal with a real component I_k and an imaginary component Q_k, the signal

obtained after the first delayed multiplication is in turn complex having a real component ($DOT^{(1)}_k$) and an imaginary component ($CROSS^{(1)}_k$):

- for performing the first delayed multiplication, the quantity $I_kI_{k-1}+Q_kQ_{k-1}$ is calculated, supplying the real component ($DOT^{(1)}_k$) of the new signal, the quantity $Q_nI_{n-1}-I_nQ_{n-1}$ is calculated, supplying the component ($CROSS_k^{(1)}$) of the new signal,

- for performing the second delayed multiplication, the quantity $(DOT_k^{(1)})(DOT^{(1)}_{k-1})+(CROSS^{(1)}_k)(CROSS^{(1)}_{k-1})$ is calculated, giving the real component ($DOT^{(2)}_k$) of the final signal, and the quantity $(DOT^{(1)}_{k-1})(CROSS^{(1)}_k)-(DOT_k)(CROSS^{(1)}_{k-1})$ is calculated, giving the imaginary component ($CROSS^{(2)}_k$) of the final signal.

5. A CDMA signal receiver for implementing the method according to claim 1, this receiver comprising:

- correlation means (10(I), 10(Q)) functioning with appropriate pseudo-random sequences, and delivering a sampled correlation signal,

- synchronization means (16) for delivering a synchronization signal (S) localizing data within the correlation signal,

- decoding means (16) for retrieving the data (D),

this receiver being characterized in that the synchronization means is a double delayed multiplication means of the sampled correlation signal comprising means (50, 52, 54), (60, 62, 64) capable of performing a first delayed multiplication consisting in multiplying a sample of the correlation signal by the

conjugate preceding sample, then a second delayed multiplication consisting in multiplying a sample of the signal thus obtained by the conjugate preceding sample of said signal obtained.

ABSTRACT OF THE DISCLOSURE

METHOD FOR RECEIVING CDMA SIGNALS WITH SYNCHRONIZATION BEING OBTAINED THROUGH DOUBLE DELAYED MULTIPLICATION, AND ASSOCIATED RECEIVER

The present invention relates to a method for receiving CDMA signals with synchronization being obtained through double delayed multiplication, and an associated receiver.

According to the invention, the correlation signal undergoes double delayed multiplication. Synchronization is established on the signal thus generated.

Applied to digital communications, in particular with mobile phones.

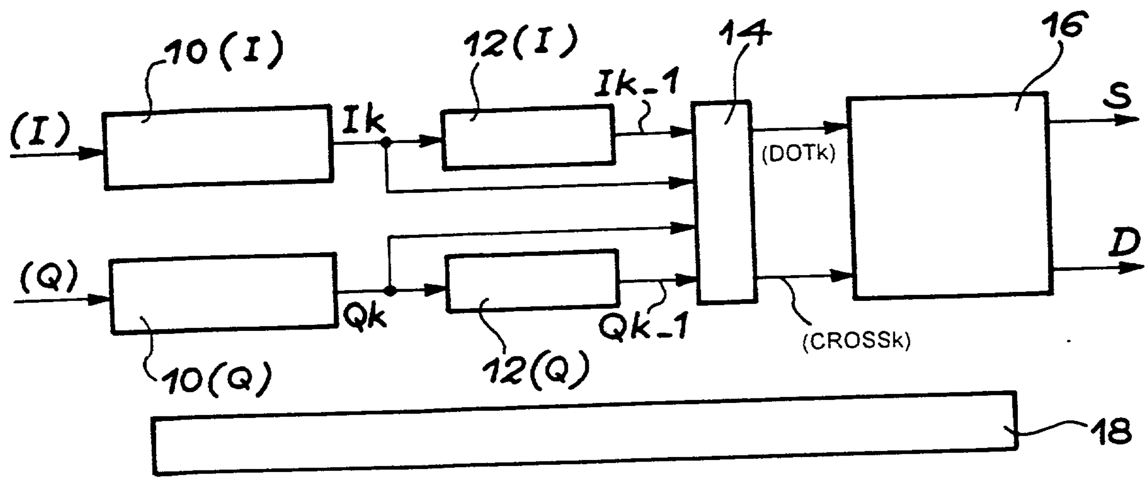

FIG. 1

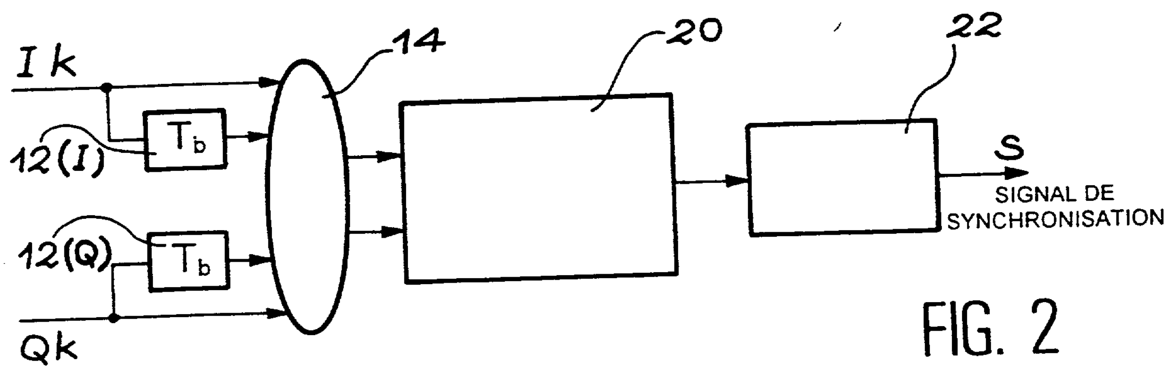

FIG. 2

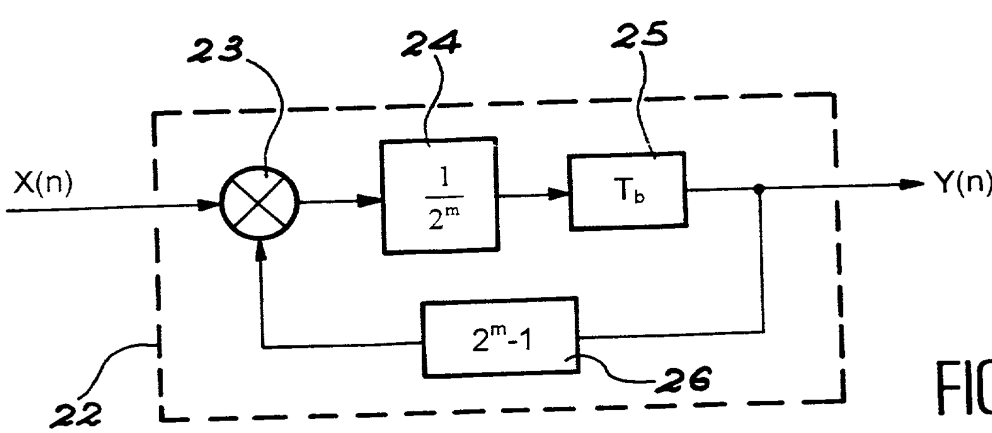

FIG. 3

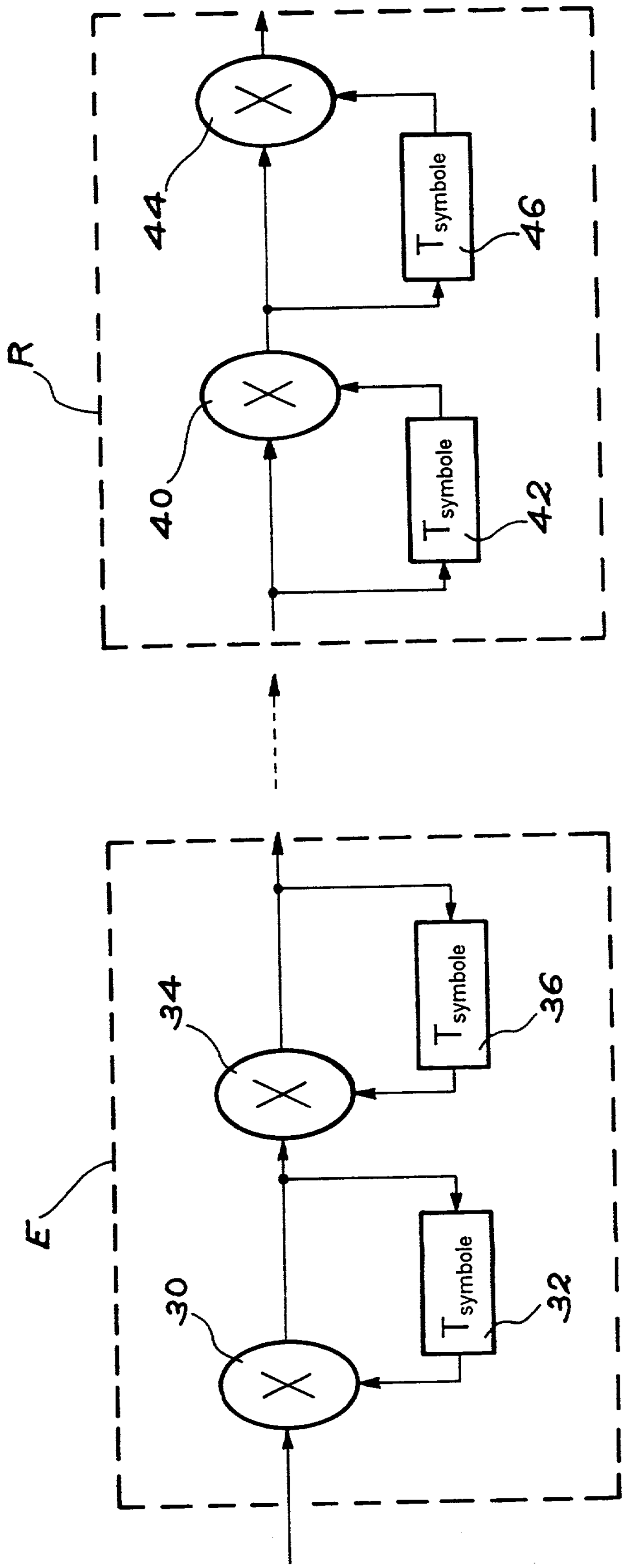
R
E
30
32
34
36
40
42
44
46
T symbole
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FIG. 4

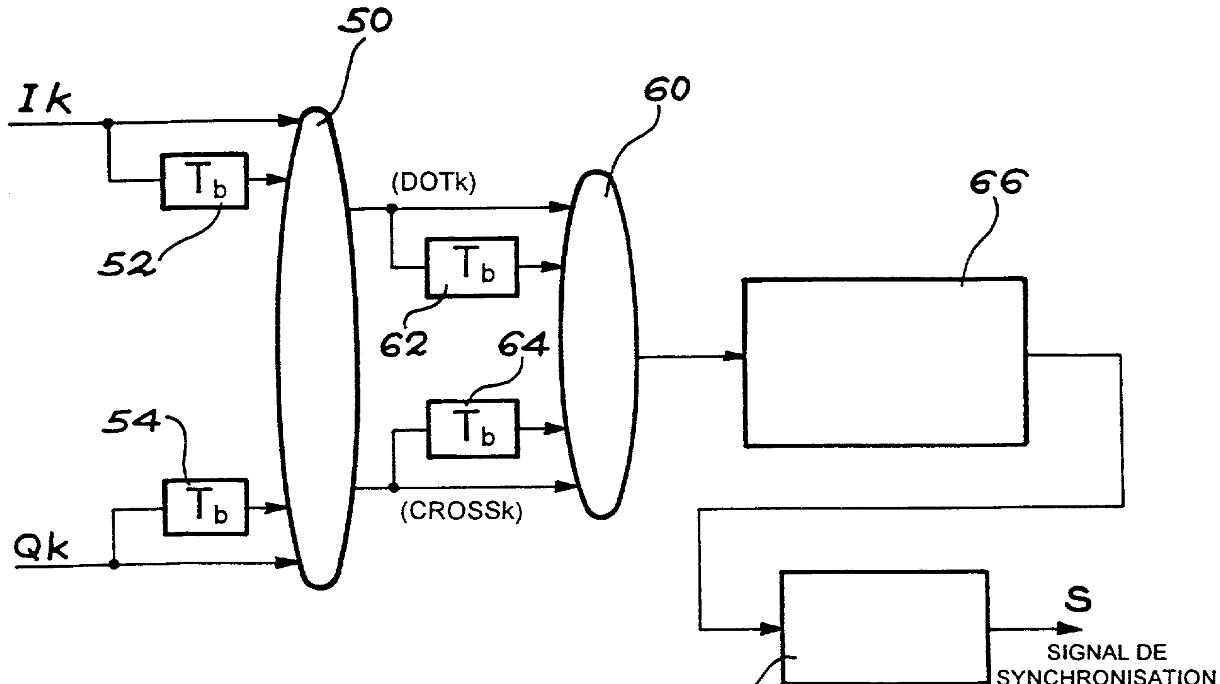

FIG. 5

SYNCHRONIZATION SIGNAL

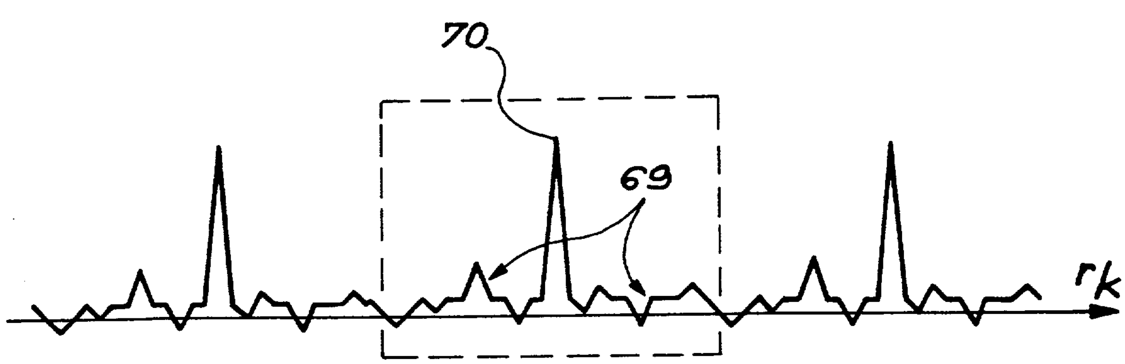

FIG. 6

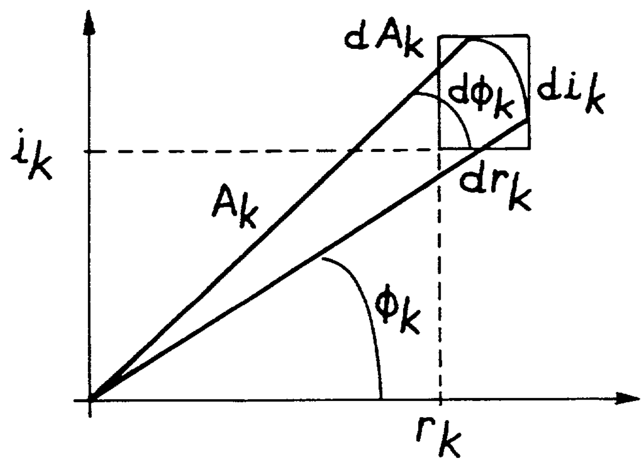
dA_k
$d\phi_k$
di_k
i_k
dr_k
A_k
ϕ_k
r_k

FIG. 7

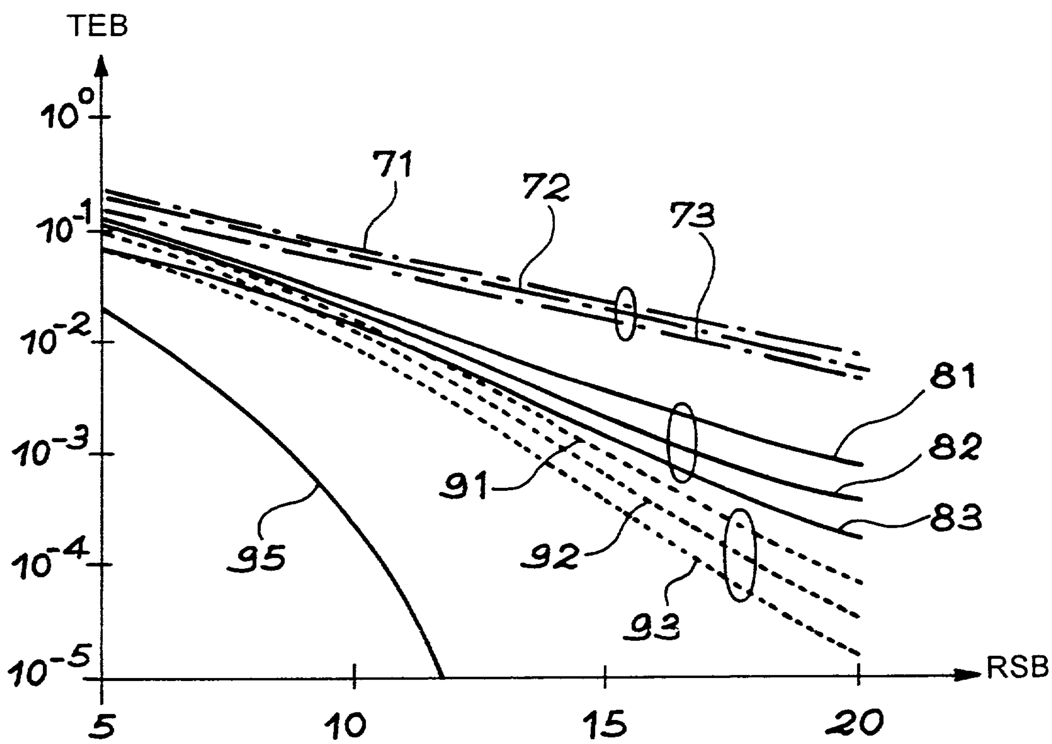
TEB
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
71
72
73
81
82
83
91
92
93
95
RSB
5
10
15
20

FIG. 8

B 13128.3 RS

Declaration, Power Of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled
METHOD FOR RECEIVING CDMA SIGNALS WITH SYNCHRONIZATION BEING OBTAINED THROUGH DOUBLE DELAYED MULTIPLICATION, AND ASSOCIATED RECEIVER.

the specification of which

☐ is attached hereto.

☐ was filed on
as Application Serial No.
and amended on

☒ was filed as PCT international application
Number PCT/FR99/02102
on September 03, 1999
and was amended under PCT Article 19
on June 16, 2000

COPY

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

Application No.	Country	Day/month/Year	Priority Claimed	
98 11087	FRANCE	04 September 1998	☒ YES	☐ NO
			☐ YES	☐ NO
			☐ YES	☐ NO
			☐ YES	☐ NO

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.	Filing Date	Status (pending, patented, abandoned)

28

And we (I) hereby appoint : Norman F. Oblon, Registration Number 24,618; Marvin J. Spivak, Registration Number 24,913; C. Irvin McClelland, Registration Number 21,124; Gregory J. Maier, Registration Number 25,599; Arthur I. Neustadt, Registration Number 24,854; Richard D. Kelly, Registration Number 27,757; James D. Hamilton, Registration Number 28,421; Eckhard H. Kuesters, Registration Number 28,870; Robert T. Pous, Registration Number 29,099; Charles L. Gholz, Registration Number 26,395; William E. Beaumont, Registration Number 30,996; Jean-Paul Lavalleye, Registration Number 31,451; Stephen G. Baxter, Registration Number 32,884; Richard L. Treanor, Registration Number 36,379; Steven P. Weihrouch, Registration Number 32,829; John T. Goolkasian, Registration Number 26,142; Richard L. Chinn, Registration Number 34,305; Steven E. Lipman, Registration Number 30,011; Carl E. Schlier, Registration Number 34,426; James J. Kulbaski, Registration Number 34,648; Richard A. Neifeld, Registration Number 35,299; J. Derek Mason, Registration Number 35,270; Surinder Sachar, Registration Number 34,423; Christina M. Gadiano, Registration Number 37,628; Jeffrey B. McIntyre, Registration Number 36,867; William T. Enos, Registration Number 33,128; Michael E. McKabe Jr., Registration Number 37,182, Bradley D. Lytle, Registration Number 40,073 and Michael R. Casey Registration Number 40,294 ; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C., whose post Office Address is : Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

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